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Supplementary material on the Lake Bonney siphon

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Figure 1. Water entering Lake Bonney from the siphons shown in figure 6 in the main body of the paper. Note the pelicans hoping to catch fish congregating near the outflow.

Much of Australia has been in drought over the last several years due to an *El Nino* event. South Australia has been particularly hard hit. South Australia normally receives very little rainfall and the state capital Adelaide depends on the River Murray for its water supply. Agriculture in the *Riverland* of South Australia, a region roughly 100 km in length 200 km east of Adelaide is entirely dependent on water obtained from the River Murray.

In order to reduce the amount of water lost from the Murray River system, flat areas connected to the River Murray (called *flats*) have been closed off to reduce the loss of water due to evaporation. One such example is the connection between Lake Bonney and the River Murray which was cut off in September 2007 causing the water level in the lake to fall.

To view a map of this area and satellite photos go to http://maps.google.com.au/ and zoom in on South Australia and continue to zoom in on the Berri Peringa region until you see Barmera. Lake Bonney can also be seen on Google Earth – go to 34º 11' 53.53" S, 140º 25' 28.29" E. The siphons were located where the Morgan Road crosses a channel between Lock Luna and Lake Bonney. In February 2008 the satellite photo showed the lake when it was connected to the River Murray. The Barmera pier can just be seen on maximum zoom of the satellite image.

The basic statistics for Lake Bonney taken from http://www.riverlandlocal.com.au are shown in the table 1.

Table 1. Basic information relating to Lake Bonney.

Depth	3-4 m
Circumference	15 km
Length	6.5 km
Width	4 km
Surface area	1687 hectares (ha)
Volume	58. 9 Gl

The daily evaporation rate from Lake Bonney is estimated at 98.9 Mega litres (Ml) corresponding to a drop in the surface water level of about 6 mm per day. In mid 2008 dead fish[1] were found along the shores of Lake Bonney and a decision was made to raise the water level of the lake[2].

By October 2008 the level of Lake Bonney had fallen 1.23 m below pool level[3]. (The change in the water level of Lake Bonney between Sep 2007 and March 2008 is available in graphical form in a report on the internet[4]). The Federal government obtained a 10 Giga litre (Gl) water allocation for Lake Bonney and at the beginning of December 2008, 18 siphons of

[1] http://www.independentweekly.com.au/slideshowplayer.aspx?id=4375

[2] http://www.independentweekly.com.au/slideshowplayer.aspx?id=4375

http://www.independentweekly.com.au/news/local/news/general/scale-of-lake-bonney-fish-kill-worsens/1373012.aspx

[3] The level of the River Murray close to the location of Lake Bonney

[4] http://www.samdbnrm.sa.gov.au/TheDrought/DroughtWetlandMonitoring/LakeBonneyWaterLevels/tabid/1586/language/en-AU/Default.aspx

200 mm internal diameter polypipe began transferring water over the barrier built between Chambers Creek and Lake Bonney.

Since the refilling operation began, huge numbers of fish have been congregating around the pipes (seen on the video clip). In the early days of the operation of the siphon, fishermen were catching four tons of fish each day. Filling began on 1 December 2008 and finished on the 21st January 2009, 50 days in total. It is easy to see that 10 G1 of water is equal to about 100 days worth of evaporation, therefore the refilling operation has delayed the drying up process by three months. After completion of the siphon operation in January 2009, the siphons were removed.

Options considered for re-filling Lake Bonney

A report issued in June 2008 entitled *Potential Impacts from Extended Closure of Lake Bonney*[5] issued by the South Australian Murray-Darling Basin Natural Resources Management Board discusses the options for re-filling Lake Bonney. One option discussed was the installation of a diesel pump on the embankment between Lake Bonney and Chambers Creek. When the report was published in the middle of 2008, the estimated cost of this option was AUS$ 700,000. However, this was before the crash in fuel prices that occurred as a result of the global financial crises in the latter half of 2008 - therefore the cost of this option would have been considerably cheaper at the time of re-filling, although this was unknown at the time and in June 2008 the indications were that the price of fuel would continue to increase.

A second option considered was the construction of two engineered concrete pipes through the embankment between Chambers Creek and Lake Bonney at an estimated cost of $250,000. A third option was to use the existing network of pipes between the River Murray and Lake Bonney with an estimated cost of $30/Ml for a total cost of $300,000.

The estimated cost of the siphon was $30,000. Therefore the siphon saved at least $250,000 – $30,000 – $222,000 and was environmentally friendly. A diesel engine running continuously for 50 days in the same location would be bound to pollute the local environment with oil and exhaust fumes. The abundant wildlife near the water outflow – for example the pelicans looking for fish seen in figure 1 and briefly in the video clip – would particularly be at risk. The siphon was the clear winner amongst the options considered in terms of cost and environmental impact.

Calculation of the water level rise in Lake Bonney

When the siphoning began, the water level of Lake Bonney was 1.3 m below pool level (i.e. the level of the water in Chambers Creek connected to the River Murray). Therefore, at the beginning of the siphoning operation, the head of water driving the flow through the siphon was 1.3 m, which reduced as the water level rose in Lake Bonney. The purpose of the refilling operation was to raise the water level of Lake Bonney by ~0.6 m. The following calculation confirms that based on the surface area of Lake Bonney, the addition of 10 Ml will raise the water level by 0.6 m.

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5 http://www.samdbnrm.sa.gov.au/Portals/7/Potential%20impacts%20from%20extended%20closure%20June%2008%20Final.pdf

1 hectare (ha) is equal to 100 m × 100 m = 10^4 m^2, so the area of Lake Bonney in square metres is equal to 1687 $\times 10^4$ = 1.687 × 10^7 m^2, this amount of water will raise the water level by about:

$$V = A \times d \therefore d = \frac{V}{A} = \frac{10^7}{1.7 \times 10^7} = 0.6 \text{ m}$$

Calculation of the average flow rate in the refilling operation
The refill operation ran for 50 days from the beginning of December 2008 to 20th January 2009[6], therefore the average flow rate for each pipe over this time was:

$$= \frac{10^{10}}{50 \times 24 \times 3600 \times 18} = 128 \, \text{ls}^{-1}$$

Use of the siphon equation to cross-check the average flow in the siphons
We can use the equation for the velocity of the water flowing out of a siphon to check the flow rate of 128 l s^{-1} for each pipe. We will assume that the average siphon height throughout the refilling operation was 1 m. The average flow rate was then:

$$= \sqrt{2gh} = \sqrt{2 \times 9.8 \times 1} = 4.4 \text{ ms}^{-1} = 440 \text{ cm s}^{-1}$$

The flow rate is the average velocity multiplied by the area of the pipe. (The velocity and area have been calculated in cm to make it easier to convert to litres). The area of the pipe is given by

$$\pi r^2 = 3.14 \times (10)^2 = 314 \text{ cm}^3$$

For an internal pipe diameter of 200 mm, the flow rate is

$$= 4.40 \times 314 = 1.38 \times 10^5 \text{ cm}^3 = 138 \text{ l s}^{-1}$$

Notice that this value is very close to the average filling rate calculated above. In practice the velocity of the water flowing out of the siphon would be slower due to friction and turbulence. More detailed calculations could be done taking into account non-laminar flow.

How much energy would be required to raise 10 Gl by 1 m?
It is interesting exercise to calculate how much energy would be required to raise 10 Gl of water 1 m. The amount of energy (*PE*) required to lift 10 Gl of water 1 m is:

[6] Fortuitously I visited the site on the last day of siphoning!

$$PE = mgh = 10^{10} \times 9.8 \times 1 \approx 10^{11} \text{ J}$$

If electric pumps were used to raise 10 Gl of water by 1 m, 1 kwh is 3.6×10^6 J of energy, so

10^{11} J is equivalent to:

$$\frac{10^{11}}{3.6 \times 10^6} = 2.8 \times 10^4 \text{ kWh}$$

Assuming the cost of electricity was 15 c /kWh, the total cost of pumping 10 Gl to a height of 1 m would be $2.8 \times 10^4 \times 0.15$ = $4,166. Since water pumps are about 80% efficient and electric motors 92% efficient, the total efficiency of pumping water is about 73.6%, therefore the total cost would be about 4,166/0.736 = $5,660.